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Patents ADP number *(if you know it)*

If the applicant is a corporate body, give the country/state of its incorporation

4. Title of the invention

ELECTRICAL BATTERY INTERCONNECT DEVICE

5. Name of your agent *(if you have one)*

"Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*

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Description 8 / 8

Claim(s)

Abstract

Drawing(s)

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ELECTRICAL BATTERY INTERCONNECT DEVICE

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Brunel University

The present invention relates to an electrical battery interconnect and a system for producing such a battery interconnect.

Printed Battery interconnect Structures:

One of the applications of this technology is in the fabrication of low cost battery interconnect structures using lithographic printing processes.

This invention relates to a novel form of flexible circuitry for battery interconnection. It is extremely cheap to manufacture, is flexible, and offers finer line resolution than that which can be produced by many other polymer thick-film approaches to flexi-circuit manufacture. Large currents (in excess of an amp) may be carried by use of thick lines printed on both sides of the substrate.

Connection to conductors may be made by use of a range of interconnection devices, either mechanical, or attached using conductive adhesive, to the conductive tracks.

Passive components may be printed directly into place in the interconnection circuitry, using a range of lithographic resistive and dielectric inks.

The whole structure may be laminated, or over printed with a protective varnish layer, to produce a robust device.

The lithographic printing process may be used to print battery interconnects directly onto flexible substrates. The application of this work is in battery interconnect, battery interconnect patterns can be printed directly onto flexible substrates which can then be mounted onto planar surfaces to form the battery interconnecting elements of battery interconnect, or planar battery interconnect structures, or to contoured surfaces to form 3-dimensional battery interconnect structures.

A lithographically printed battery interconnect may be fabricated by lithographic printing, the printed battery interconnect components being formed by a composition of materials, which form a lithographic ink, include a conductive material mixed with a resin, solvent and additives to make a paste-like composition as disclosed herein in the Ink section. The ink is adhered to a substrate in an appropriate configuration. Printed battery interconnects described in the prior known systems are printed using alternative thick film methods, for example via a screen printing process, not via a lithographic printing process or lithographic printing ink.

One embodiment provides a lithographically printed Battery interconnect. The battery interconnect includes a dielectric substrate, an interconnect and battery interconnect structure having electrical properties being imprinted on the surface of the substrate. The battery interconnect structure is formed of electrically conductive particles and a binder for retaining the conductive particles in an oriented relation, thereby providing for electrical conductivity through the battery interconnect. A unique feature of the battery interconnect is that its material composition is suitable for deposition using the lithographic printing process. This method by which the battery interconnect is formed, permits the battery interconnect to be fabricated in a simple and inexpensive manner.

It is contemplated that the substrate on which the battery interconnect is printed will be formed of a dielectric material having non-conductive characteristics, preferably a plastic polymer such as polyester or polyethylene but substrates such as cellulose or synthetic polymer based paper may also be used. The kind of material from which the substrate would be selected would depend on the manner of use of the battery interconnect, and the environment in which it would be used.

The battery interconnect is formed from, and by selection of constituents of, a composition that includes particles of conductive material, such as silver powder, silver flake, palladium particulate, platinum powder, carbon black, and other suitable

conductive materials. The ink includes a binder such as a resin mixed with the conductive material. A suitable resin for binding the conductive material may be an alkyd or rosin or other suitable materials. The ink formulation when printed, yields an acceptably low sheet resistivity for many battery interconnect-pad applications.

In the mixing of the printed material for a battery interconnect, relative percentages of the materials used in the composition may be as follows:

Materials	Percentage by weight
Conductive material	15-85
Organic phase	85-15

This ink formulation when printed, yields an acceptably low sheet resistivity for many battery interconnect circuit applications.

This invention uses a lithographic processes for the manufacture of electronic and electrical circuit systems, including electrical interconnects and electrical and electronic components. The term "lithographic process" referred to herein is a process for the printing of an electrically conductive film and passive components on a suitable substrate, utilizing differences in surface chemistry of the printing plate, including hydrophilic and hydrophobic properties. It does not refer to the commonly used process involving photoresist and etching occurring during the production of etched circuit boards and/or silicon semiconductor micro electronics. The term "ink" is intended to mean any material suitable for printing.

There are several important aspects of the developed lithographic fabrication process, including

- A conductive ink
- Lithographically printed battery interconnect structure

Thus, according to an aspect of the present invention, there is provided an ink for the manufacture of an electrical battery interconnect comprising electrically conductive particles suspended in a resin.

By ink it is intended to mean any liquid suitable for printing.

Preferably, the resin is an organic resin, such as an alkyd resin.

The conductive particles preferably consist of or include metallic silver. The metal content of the ink may be in the range between 65% and 95% w/w, preferably between 65% and 90% w/w and most preferably about 80% w/w. The size of the metal particles may be in the range between 0.1 and 10 micrometres and preferably about 1 micrometre.

If aluminium or another conductive particulate is employed the w/w percentage will vary as the materials have differing densities, a metal coated particulate could be very light resulting in a low w/w percentage. A range of 15% or 20% w/w to 95% w/w is envisaged for these metals.

The inks preferably exhibits thixotropic flow properties of about 10.3 PaS @ 25°C.

According the another aspect of the present invention, there is provided an electrical battery interconnect including a substrate, and electrical battery interconnect contacts lithographically printed onto the substrate from an ink as specified herein.

The substrate may be a paper such as gloss art paper, bond paper or a semi-synthetic (for example polyester fibre) or synthetic papers (for example Polyart), or plastics (for example Polyethylene), or composite materials (for example FR4 or FR2).

An embodiment of the present invention is described below, by way of illustration only. For ease of understanding, this embodiment is described by way of its component parts.

The ink:

Ink layers deposited by the preferred lithographic printing process are about 5 micrometres (5×10^{-6}m) thick. This may be compared to about 25 micrometres for conductive layers deposited by screen printing, and 35-75 micrometres of copper typically laminated onto a conventional printed circuit board. The ink must therefore exhibit a high electrical conductivity, and yet conform to the mechanical constraints imposed by the lithographic printing process.

The adopted approach has been to formulate an ink from electrically conductive particles suspended in an organic (e.g. alkyd) resin. Although this resin is non-conductive, it acts as a vehicle for the conductive particles, and partly determines the mechanical properties of the ink. Manipulation of the resin formulation permits a degree of control over certain mechanical characteristics of the ink (e.g. viscosity). Metallic conductors, and elements falling in group IV of the periodic table, have been employed as the conductive particulate.

When printed lithographically, the resulting ink films consist of a "pebble dash" of conductive particles distributed on the substrate surface. The electrical resistance of the ink film on the macroscopic scale is considered to be dependent on the physical distribution of the conductive particles on the substrate, and on the physical contact between them.

For the printing of electrical circuits, a variety of materials may be used to formulate suitable inks. Suitable materials selected for their characteristic conductivity and chemical stability include silver powder, silver coated particles, titanium oxide, palladium, gold, allotropes of carbon or alloys or mixtures of the above-mentioned

materials and other suitable conductive materials. It is considered that the mean optimal metal particle size lies in the range 0.1 to 10 micrometres.

An organic phase as a binder mixed with the conductive material. Suitable constituents of the organic phase include a resin such as an alkyd resin, phenolic resin, hydrocarbon resin, turpene resin and rosin, suitable hydrocarbon solvents and other suitable additives used to adjust the printing, conductivity, wear resistance and drying properties of the printed layer.

The conductivity within the deposited ink film is therefore affected by:

- Particle size and shape
- Particle to resin ratio
- Resin composition

The preferred ink formulation contains a high proportion (approximately 80% w/w) of metallic silver, with a mean particle size < 1 micrometre.

Work to date has demonstrated that standard lithographic printing technology can be adapted to electronic circuit fabrication for which we have developed a conductive ink formulation with adequate mechanical and electrical properties. The preferred ink incorporates:

- Nodular silver particles whose mean particle size is less than about 1 micrometre (10^{-6}m). The resulting ink formulation exhibits thixotropic flow properties about (10.3PaS @ 25°C). It is considered that the mean optimal metal particle size lies in the range 0.1 - 10 micrometres.
- The metal content of this ink is preferably about 80% w/w. The optimal metal loading for this ink is considered to lie in the range 65% to 95% w/w, preferably between 65% and 90% w/w.

- If aluminium or another conductive particulate is employed the w/w percentage will vary as the materials have differing densities, a metal coated particulate could be very light resulting in a low w/w percentage. A range of 15% or 20% w/w to 95% w/w is envisaged for these metals.

The range of particle sizes present in the ink is considered to influence film conductivity, and that a combination of particle sizes provides a higher probability of inter-particle contact, with smaller particles filling voids between larger particles. The ink formulation when printed has been found to yield a sufficiently low sheet resistivity for many circuit applications.

An example formulation of a conductive ink is:

Silver powder particulate possessing a mean particle size of 5.5 micrometres	80% by weight
Hydrocarbon resin containing a styrenated alkyd	16% by weight
High boiling point solvent with about 24% aromatic content	3.5% by weight
Antioxidant	0.5% by weight

The resulting ink formulation exhibits thixotropic flow properties, exhibiting a viscosity of about 10^{-4}mPaS @ 25 degrees C. Suitable viscosities of ink formulations are considered to lie within 10^{-3}mPaS @ 25 degrees C and 10^{-6}mPaS @ 25 degrees C.

It has been demonstrated that standard lithographic printing technology can be adapted to electrical circuit fabrication for which we have developed a conductive ink formulation with adequate mechanical and electrical properties.

The Substrate:

FR4 and FR2 circuit board substrates in widespread use are glass fibre and paper materials impregnated with epoxy resins and other additives such as fire retardants and fungicides. The preferred lithographic process requires the substrate to be both flexible and have a degree of affinity towards the printed ink.

Substrate considerations for successful circuit fabrication include:

- Substrate surface topography
- Material properties

Substrate topography influences the quantity of ink laid down and whether the particles of conductor are likely to be in contact with their neighbours.

The material properties of the substrate that must be considered include moisture resistance, dielectric properties, flame retardancy, temperature cycling and mechanical strength.

Trials have included Gloss art, bond, synthetic papers, plastics and composite substrates. Many of these can have surface coatings or treatments applied to enhance particular characteristics. The conductivity of the deposited films is dependent upon the surface characteristics of the substrate and the ink. Similar conductivities are achievable across a range of substrates, enabling substrates to be selected for other characteristics, such as cost, flexibility and weight.

It is envisaged that paper substrates could be coated or impregnated with conformal agents (e.g. waterproofing compounds or fire retardants) in certain circumstances.

Printing trials have yielded ink films deposited onto paper substrates which have acceptable electrical characteristics and which have subsequently been assembled into functional electronic battery interconnects.